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The Relationship of Hitting Ability in Baseball to Selected Anatomical Measurements and Motor Responses

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THE RELATIONSHIP OF HITTING ABILITY IN BASEBALL TO SELECTED ANATOMICAL MEASUREMENTS AND MOTOR RESPONSES

BY

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TO SELECTED ANATOMICAL MEASUREMENTS

AND MOTOR RESPONSES

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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CHAPTER I

INTRODUCTION

Significance of the Study

Batters in all classifications of baseball, whether on the little league level or on the major league level, consistently strive for hitting proficiency. They know that baseball games are won by scoring runs. Hitting is a very important part of baseball but even the best hitters fail more than sixty percent of the time to hit safely. An example of this problem is evident in surveying the averages of the batting champions of the National and American League. During the years of 1928, 1948, and 1968, the National League batting champions had averages of .387, .376, and .335, respectively, and the American League batting champions had averages of .379, .369, and .301 respectively.[1]

In a closer examination, one can note the constant decline in batting averages. The present era seems to be more of a pitcher's paradise. According to Duke Snyder, former Dodger slugger, the pitchers have been taking over the game and have so dominated the game that the day of the four-hundred hitter has probably disappeared.[2]

In light of the decrease in batting averages in baseball competition, the development of a method whereby hitting consistency might be improved seems imperative. Identifying the specific skills related to

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[1] The Baseball Encyclopedia (The Macmillian Company, Collier-Macmillian Canada Ltd., Toronto, Ontario, 1969), pp. 150-160.

[2] "Where Are the Hitters?," Newsweek, 71:86, June 3, 1968.

hitting success and their subsequent emphasis by the players and coaches involved could do much toward achieving the desired results which in turn would lead to increased spectator interest.

Statement of the Problem

The purpose of this study was to investigate the relationship between right grip strength, left grip strength, right wrist strength, left wrist strength, trunk strength, kinesthetic perception, peripheral vision, depth perception, reaction time, speed of movement time, hand-eye coordination, agility and leg power with the ability of a batter to hit a baseball. A secondary purpose was to develop a regression equation from the independent variables which could be used to predict hitting success.

Hypotheses

1. There is no significant relationship between hitting a baseball and selected anatomical measurements and motor responses.

2. A multiple regression equation to significantly predict hitting ability in baseball cannot be developed.

Limitations and Delimitations

1. Eighteen athletes from the South Dakota State University baseball team were used as subjects.

2. The subjects consisted entirely of right-handed batters.

3. Indoor hitting data were collected as a result of subjects batting against a pitching machine and live pitching in batting cages. Outdoor hitting data were collected as a result of subjects hitting against opposing teams' pitching in game situations.

4. Only the ability to hit the baseball in fair territory was investigated.

5. Right grip strength, left grip strength, right wrist strength, left wrist strength, trunk strength, kinesthetic perception, peripheral vision, depth perception, reaction time, speed of movement, hand-eye coordination, agility and leg power were the variables investigated.

Definition of Terms

Agility. The physical ability which enables an individual to quickly change body position and direction in a precise and quick manner.[3]

Depth perception. The coordination of both eyes to discriminate a third dimension in one's environment and to adjust oneself in relation to objects in the visual field.[4]

Hand-eye coordination. Hand-eye coordination indicates a good working relationship between the eyes and the neuromuscular system.[5]

Hitting ability. Hitting ability is the ability to hit the ball within the foul lines. The batters did not have to reach base safely.

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[3]Barry L. Johnson and Jack K. Nelson, Practical Measurements for Evaluation in Physical Education (Minneapolis: Burgess Publishing Company, 1969), p. 100.

[4]B. Clark and J. Warren, "Depth Perception and Inter-Pupillary Distance as Factors in Proficiency in Ball Games," American Journal of Psychology, 47:485-7, 1935.

[5]Donald K. Mathews, Measurement in Physical Education (Philadelphia: W. B. Saunders Company, 1968), p. 168.

Kinesthetic perception. Kinesthetic perception is the ability to perceive the position and movement of the body and its joints during muscular action which is also referred to as the sixth sense.[6]

Leg power. Leg power is the distance the legs can propel a body or an object through space.[7]

Peripheral vision. Peripheral vision is the ability to differentiate objects from their surroundings in the peripheral field of vision.

Reaction time. Reaction time is the interval of time between the presentation of the stimulus and the initiation of the response.[8]

Strength. Strength is the maximum force which a muscle or group of muscles can exert with one contraction.[9]

Speed of movement time. Speed of movement can be defined as the rate at which a person can propel his body, or parts of his body, through space.[10]

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[6] Johnson and Nelson, op. cit., p. 182.

[7] Ibid.

[8] Ibid., p. 227.

[9] Henry J. Montoye (ed.), An Introduction to Measurement in Physical Education, Vol. 4, Physical Fitness (Indianapolis, Indiana: Phi Epsilon Kappa Fraternity, 1970), p. 1.

[10] Johnson and Nelson, op. cit., p. 227.

CHAPTER II

REVIEW OF RELATED LITERATURE

Considerable research has been completed in the area of testing general motor ability and ability in specific athletic activities. However, few studies have been completed that touched briefly on all phases of baseball or upon specific areas of baseball potential. The review of literature chapter was concerned with those studies which deal with baseball ability and with those which deal specificially with the variables being investigated in this study.

Literature Related to Grip, Wrist, and Trunk Strength

Although little research has been conducted in relation to baseball and grip strength, Jesse simply says that the grip should be relaxed.[1] On the other hand, Puck claims that a firm grip must be used at contact of the bat and baseball in order to apply as much force as possible to the baseball.[2]

According to Hooks in his study of the effects of strength on hitting, he found a low correlation of .32 for grip strength while batting against a pitching machine.[3]

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[1]David E. Jesse, Baseball (New York: A. S. Barnes and Company, 1938), p. 70.

[2]Paul Edward Puck, "Cinematographical Analysis of Effective Batting Performance," (unpublished Master's thesis, Illinois State University, Bloomington, Illinois, 1964), pp. 1-84.

[3]Gene Hooks, "Prediction of Baseball Ability Through an Analysis of Measures of Strength and Structure," Research Quarterly, 30:38-43, March, 1959.

Williams states that to be a better hitter, one must develop strong, quick hands and wrists which whip the bat through the ball at the instant of impact.[4]

In the explanation of batting by Cooper and Glassow, they stated that "strong wrist muscles are important, for the heavy bat must be moved rapidly if the potential of wrist action is to be realized."[5]

Conrad concluded that higher skilled batters used more wrist action just prior to hitting the baseball than less skilled batters. Also the higher skilled batter performs his swing movement in a more consistent manner getting most of his velocity from his wrist action and he does not appear to swing so hard that he does not have his bat under control throughout the swing.[6]

As a result of a study conducted by Puck, the following conclusions were drawn:

1. The body segments contributing most to the force involved in effectively batting a pitched ball were the hips and shoulders in trunk rotation.

2. The angle of inclination of the trunk remained relatively constant throughout the action of all four subjects.

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[4] Ted Williams, "How To Be a Better Hitter," Scholastic Coach, 25:8, April, 1956.

[5] John M. Cooper and Ruth B. Glassow, Kinesiology (St. Louis: The C. V. Mosby Company, 1963), pp. 85-88.

[6] Ruth Conrad, "A Cinematographical Analysis of the Major Sequential Movement Patterns of Skilled, Semi-Skilled, and Non-Skilled Baseball Batters," (unpublished Doctoral dissertation, Temple University, Philadelphia, Pennsylvania, 1965), pp. 101-103.

3. Trunk rotation was completed before the forward motion of the arm swing began.

4. The trunk rotation, occurring between the start of the action and contact of the bat with the ball, averaged 119 degrees for the four subjects.

5. The trunk rotation first involved rotation of the hips, during which the shoulder rotation remained constant or was even slightly in opposition to hip rotation.[7]

According to Hooks, "When an individual's strength is noticeably increased, there is a definite improvement in his ability." Experiments conducted by Hook have shown a very high correlation between left shoulder flexion and success in hitting.[8]

Stallings has written the following concerning weight training and strength for baseball players:

> All baseball men will agree that a degree of physical strength is necessary to be able to play the game with some skill. Weight training offers the best answer for the young ballplayer not blessed with it.[9]

Crawford concluded that simple girth of the trunk is not a significantly reliable method of predicting strength.[10]

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[7]Puck, op. cit., pp. 51-53.

[8]Hooks, op. cit., p. 39.

[9]Jack Stallings, "The Case for Weight Training in Baseball" Scholastic Coach, 35:61, February, 1966.

[10]Fred J. Crawford, "Relations of Girth of Limbs and Trunk to Muscle Strength in Adults," (unpublished Master's thesis, State University of Iowa, Iowa City, 1936), p. 65.

Bunn explained the sequence of movement as follows:

> "The batter steps first . . . as the foot is placed, the body starts to rotate at the shoulders and the hips. Finally, the forearms extend and as the ball is met, the wrists are quickly extended . . . The movements must be in sequence and started at the right moment to assure the greatest effective force. The extension of the forearm and wrists are the most important moves to give increased linear velocity to the bat for the same angular velocity."[11]

Watts states that "maximum driving power is affected by quick action of the arms and hips and upon rapid acceleration of the swing at the moment of impact."[12]

According to Scott, "the backswing is made by shifting the weight . . . rotation of the trunk to the right about twenty degrees to thirty degrees and lifting the bat backward in nearly a horizontal swing until it is almost behind the head."[13] A description of the mechanical analysis of the skill of batting included the statement, "The maximum speed is attained by the combination of weight transfer, rotation of the body, and the swing of the extended arms . . . . Perfect timing is necessary if the maximum accuracy and momentum are to be attained."[14]

Race studied seventeen proficient, professional batters of the Eastern League. In this cinematographic study, he measured the velocities of major body segments (rotary hip motion, hand and wrist action, and the

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[11]John W. Bunn, Scientific Principles of Coaching (Englewood Cliffs, New Jersey: Prentice Hall, 1960), p. 149.

[12]Lew Watts, "Hit With Power!" Scholastic Coach, 27:13, April, 1958.

[13]M. Gladys Scott, Analysis of Human Motion (New York: Appleton Century-Crofts, 2nd Edition, 1963), p. 238.

[14]Ibid.

stride). He concluded that rotary motion is started "by rather drastic hip rotation and culminated by quick and powerful wrist action."[15]

Literature Related to Kinesthetic Sense

In a study of the relationship of four kinesthetic tests and motor ability scores, Roloff found a correlation of 0.42. This correlation was significant at the one percent level of confidence.[16]

In an early study also concerned with kinesthetic perception, Kerr and Weinland tested the hypothesis that muscular perceptivity is involved in all muscular work. They concluded that athletes were superior to non-athletes in the test of muscular perceptivity.[17]

In a study of tests of kinesthesis, Weibe noted that there was a kinesthetic difference in favor of athletes over non-athletes. Thirty men students at the University of Iowa were selected as subjects and were divided into groups of athletes and non-athletes. The athletes were selected by their coaches as being the best all-around athletes on their teams, and non-athletes were men who never earned a varsity letter in college. He found low intercorrelation between kinesthetic tests; furthermore, he felt that the low intercorrelation between tests

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[15]Donald E. Race, "A Cinematographic and Mechanical Analysis of the External Movements Involved in Hitting a Baseball Effectively," Research Quarterly, 32:394-404, October, 1961.

[16]L. L. Roloff, "Kinesthesis in Relation to the Learning of Selected Motor Skills," Research Quarterly, 24:210-217, May, 1953.

[17]W. H. Kerr and J. D. Weinland, "Muscular Perceptivity as a Trade Test," The Journal of Applied Psychology, 17:550-558, 1933.

indicated that there is no general kinesthetic sensitivity, but that there are probably numerous specific factors.[18]

Phillips and Summers found in a study of kinesthetic perception and motor learning that in a group of 115 Indiana University college women, the following occurred: (1) there was a relationship between motor learning and the positional measures of kinesthesis, (2) the kinesthetic sense was more important in the early stages of learning a motor skill than in the later stages, and (3) there are real differences between the preferred and non-preferred areas in kinesthetic sense.[19]

One of the studies made by Phillips attempted to investigate the relationship between kinesthesis and early performance tests in two perceptual-motor skills. He gave ten kinesthetic tests to a group of college men. The two perceptual-motor skills were playing a ten foot putt and playing a golf ball for accuracy at a target eighteen feet from the tee. Phillips had a low, positive relationship between certain phases of kinesthesis and success in performance during early stages of acquiring the skill. However, with some phases of kinesthesis, he found zero and negative correlation.[20]

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[18] V. R. Wiebe, "A Study of Test of Kinesthesis," Research Quarterly, 25:222-230, May, 1954.

[19] M. Phillips and D. Summers, "Relation of Kinesthetic Perception to Motor Learning," Research Quarterly, 25:456-469, December, 1954.

[20] Bernath E. Phillips, "The Relationship Between Certain Phases of Kinesthesis and Performance During the Early Stages of Acquiring Two Perceptuo-Motor Skills," Research Quarterly, 12:571, December, 1941.

Young gave nineteen tests to a group of college women. She suggested that three of these tests might be used as a battery of tests for additional research in the study of kinesthetics. These three items gave a multiple correlation of .984 when correlated with the score on all nineteen tests. The tests recommended were arm, leg raising, and balance stick.[21]

Fisher used the Young battery of kinesthesis tests in a study made with high school girls. She found a low but positive correlation between the kinesthesis test and general motor ability capacity. The correlations were too low for individual prediction. She recommended using two of the three Young tests, which were arm raising, balance stick, and a target pointing test.[22]

A number of studies made on teaching methods have stressed mental practice. Some experiments have been made with the eyes closed. Bass found that an individual used his kinesthetic mechanism less when the eyes are open than when they are closed. The semicircular canals do not seem to function in ordinary tests of balance with the eyes open as much as they do when the eyes are closed. The eyes may be the most significant factor in balance.[23]

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[21] Olive G. Young, "A Study of Kinesthesis in Relation to Selected Movements," Research Quarterly, 16:227-287, 1945.

[22] Rosemary Fisher, "A Study of Kinesthesis in Selected Motor Movements," (unpublished Master's thesis, State University of Iowa, Iowa City, 1945), p. 31.

[23] Ruth I. Bass, "Analysis of the Components of Tests of Semicircular Canal Function and of Static and Dynamic Balance," Research Quarterly, 10:33-52, 1939.

In a study on the learning of skills by women of low motor ability, Lafuze gave the following three tests to college women of both low and high motor ability: arm raising, leg raising, and pointing to a target. The reliability coefficient on the first two of these tests was found to be extremely low. The scores on the first two of the tests favored the low motor ability group while the scores on the third favored the higher motor ability group.[24]

The "Victory Through Fitness" Workshop suggested four tests which might be used to measure kinesthetic perception. Those tests were called Reproducing Foot Positions, Walking on a Path, Pointing to a Target, and Throwing at a Target. The Workshop reported, along with most writers, that kinesthetic perception was important to the ability to perform motor skills but that very little was known about measuring it.[25]

Many writers refer to the "feel" of movement. Billig says, "We are agreed that good body mechanics does not depend merely on good alignment but on the balance of the various segments. This in turn depends upon the degree of mobility of these segments. There is another important element: the feeling that we are in balance. This aptitude is scientifically referred to as the kinesthetic or proprioceptive sense.[26]

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[24] Marion Janet Lafuze, "A Study of the Learning of Fundamental Skills by Freshman Women of Low Motor Ability," (unpublished Master's thesis, State University of Iowa, Iowa City, Iowa, 1950), p. 32.

[25] "Victory Through Fitness," National Association of Physical Education for College Women, Workshop, University of Wisconsin, Madison, Wisconsin, June, 1943, p. 46.

[26] Harvey E. Billig, Jr., and Evelyn Loewendahl, Mobilization of the Human Body (Stanford, California: The Stanford University Press, 1949), pp. 47-49.

As part of the project on the research program on seeing and doing, Sherman and Mooney formulated a list of principles created to apply generally to the teaching of any activity involving kinesthetic responses. Their list included thirty-two principles. A second list of twenty-two principles is more directly applicable to the physical education situation. These lists present principles which apply to teaching and stressing the importance of kinesthetic teaching.[27]

In the Scott project, twelve different tests were given to 104 college women. Included in the twelve tests were those recommended by Young, Fisher, the "Victory Through Fitness" Workshop, and Lafuze. The reliabilities and validities of eight of these tests were high enough so that the eight tests could be recommended for further study.[28]

Literature Related to Depth Perception and Peripheral Vision

Clark, in 1935, studied the effect of interpupillary distance upon depth perception in sports. He found that there was no significant relation between interpupillary distance and depth perception as measured by Howard-Dolman Test. Depth perception of a group of athletes as measured by Howard-Dolman Test does not differ significantly from that of a control group. This raised the important question in relation to depth perception as measured by the Howard-Dolman Apparatus. Either depth perception as measured by the apparatus was relatively unimportant in ball

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[27] Hoyt Sherman and Ross Mooney, "Report of the Work of the Summer Quarter," The Ohio State University, Columbus, Ohio, 1948.

[28] Scott, op. cit., p. 47-49.

games of batting and throwing, or the test does not give an accurate measure of depth perception. Application of the results of the Howard-Dolman Apparatus to practical situations may be seriously questioned.[29]

Adamson used a modified form of the Wheatstone Stereoscopic test which uses black arrows on white background to see if the eye can adjust to the depth differential of the arrows. He concluded that in an extended field of vision the experiments appear to show that space perception is achieved largely by the ranging or scanning of the field by the eyes. Such a scanning process can very probably be considered to be one of learning or experiences.[30]

Sherman, Professor of Fine Arts at Ohio State University, stated his theory of vision in sports as based upon his theory of perception as related to drawing and fine arts. Sherman explained his concept of the technique of hitting a baseball in the following ways:

> Essentially, the batter's problem lies in being able to judge the position of the ball as it relates to that very limited space known as the "sweet part of the bat." To judge this position, the batter must know (1) the distance from the pitcher to the batter, (2) the change in the apparent size of the ball as it moves toward the batter, and (3) realize that in order for the ball to cross the plate it must always appear to the batter to be moving away from him. This means that for the batter to make an accurate judgement of this "dimension," he must see its in-out and up-down position, i.e., direction as related to peripheral cues. The integration of the ball's apparent size and its direction in relationship to the peripheral cues, affords the basis for this accurate judgement.[31]

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[29] B. Clark and W. Warren, "Depth Perception and Interpupillary Distance as Factors in Proficiency in Ball Games," American Journal of Psychology, 47:485-487, 1935.

[30] V. Adamson, "Ocular Scanning and Depth Perception," Nature, 168:346, 1951.

[31] Hoyt L. Sherman, "Aspects of Visual Perception and Their Relationship to Motor Activity," 53rd Annual Proceedings, College Physical Education Association (Washington, D. C.: College Physical Education Association, 1950), pp. 15-16.

A recent study by Wolff, a visual consultant for the Cincinnati Redlegs, revealed:

> Vision is the key to coordination. Ted Williams has been described as an athlete with remarkable coordination at the plate. Williams merely said he could "see the ball better."
>
> Hitters who frequently swung at the ball too early or too late were not fooled by the pitcher's motion but rather by their own eyes which did not adjust to the ball's speed and direction.[32]

Montebello employed one objective method and one subjective method to determine the significance of his data relative to stereoscopic vision. First he measured the steroscopic sensitivity of varsity baseball players and non-athletes under precise laboratory conditions and compared the results of the two. Second he judged the playing performance of the skilled baseball players with their stereoscopic vision entirely occluded, in order to establish the importance of stereoscopic vision in baseball. He concluded:

> . . . The methods and tests used in this study seem to indicate that no correlations exist between the individual player's stereoscopic sensitivity and his batting average over one season of play. Also, skill to recognize change in speed of pitches demanded the greatest need for stereoscopic vision.[33]

Slater-Hammel later made a study, "Effect of Blinking Upon Reaction Time Measures." In this study, he found that a blink involves a period of black-out ranging from .1 to .3 of a second, during which time the

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[32] The Boston Sunday Herald, Study done by Dr. Bruce R. Wolff on the Cincinnati Reds Baseball Team of the National League, Photostat of article by Frank Turnan, Sr., October 28, 1962, p. 6.

[33] Robert Albert Montebello, "The Role of Stereoscopic Vision in Some Aspects of Baseball Playing Ability," (unpublished Master's thesis, Ohio State University, Columbus, Ohio, 1953), pp. 60-62.

pupil of the eye is covered. If a batter blinks during a pitch, the baseball could travel approximately nine feet.[34]

Hubbard and Seng conducted a study concerned with the visual movements of professional and university batters in game situations. They concluded that batters do not track the baseball to home plate with visual pursuit methods of the head when they swing and that the professional batters do not track the baseball all the way to the point of contact with either head or eye movements. This indicates that the batter, somewhere in the process of swinging, stops tracking the ball with his eyes and depends upon judgement and kinesthetic sense to hit the ball.[35]

Visual discrimination of depth is a highly complex process because there are so many factors which can influence the individual's final judgement. Sloan and Altman proposed that all tests of depth might be valid measures of different aspects of the visual situation. If this were so, then each test of depth may be measuring a different component of depth perception and researchers may find that depth perception is not a simple visual ability but a highly complex and composite integration of many factors.[36]

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[34]A. T. Slater-Hammel, "Effect of Blinking Upon Reaction-Time Measures," Research Quarterly, 25:338, October, 1954.

[35]Hubbard and Seng, C. N., "Visual Movements of Batters," Research Quarterly, 25:42, March, 1954.

[36]Louise L. Sloan and Adelaide Altman, "Factors Involved in Several Tests of Binocular Depth Perception," American Medical Association Archives of Ophthalmology, 52:524-543, October, 1954.

According to Mail the analysis of and reaction to visual cues is important in a wide variety of gross motor skills.[37] The ability to perceive depth has been claimed to be important to the individual who wishes to succeed in his chosen activity. McCloy listed depth perception as one of the probable requisites in motor educability. McCloy stated:

> It is highly probable that in many athletic sports depth perception is a factor of importance. The ability to field a fly ball, to intercept a hard driven ground ball in baseball, to intercept and catch a long pass in basketball, to shoot goals, and to execute many other performances would seem to be related to depth perception.[38]

Banister and Blackburn in 1931 suggested depth perception as a factor for success in batting a ball. They added the proposal that the concept of the "good eye" may not really be an eye factor at all, but rather some innate visuo-motor coordination coupled with learning, training, and/or experience.[39]

In 1956 Olsen, using a Howard-Dolman apparatus, reported significant differences in depth perception among athletes, intermediate athletes, and non-athletes. Both the athletes and the intermediate athletes possess much better depth perception than did non-athletes. Olsen felt that "It would seem from the few studies investigating depth perception in athletics, that little if any relationship exists between

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[37]Patricia D. Mail, "The Influence of Binocular Depth Perception in the Learning of a Motor Skill," (unpublished Master's thesis, Smith College, Northampton, Massachusetts, June, 1965), p. 10.

[38]Charles H. McCloy, Tests and Measurements in Health and Physical Education (New York: Appleton-Century-Crofts, Inc., 1954), pp. 497-8.

[39]H. Banister and J. H. Blackburn, "An Eye Factor Affecting Proficiency at Ball Games," British Journal of Psychology, 21:382-384, April, 1931.

the ability to discriminate distance of objects and motor performance."[40]

It has been established that the visual field extends almost 180 degrees horizontally and 130 degrees vertically. When viewed with binocular vision, the clarity with which parts of the visual field are seen depends upon the direction of line of sight. If an object is focused directly upon the fovea, clearest vision will occur. An object is seen with less acuity the more it is viewed in the periphery.[41]

Sherman's study eliminated verbal directions and greatly limited the visual perception of students in a beginning drawing class. His students sat in total darkness and saw a lantern slide model flashed on a large screen. The model was visible for but one-tenth of a second. Then within one and one-half minutes the students were required to reproduce the model. Sherman stated that students exposed to this technique, which prevented visual attention to movements, learned to reproduce drawings equally as well and in a much shorter time than students instructed by conventional methods.[42]

Sherman claimed that peripheral vision was more important than central vision because peripheral vision was sensitive to the more gross aspects of visual cues, namely position and mass, whereas central vision

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[40]Einar A. Olsen, "Relationship Between Psychological Capacities and Success in College Athletics," Research Quarterly, 27:79-89, March, 1956.

[41]William Howell, A Textbook of Physiology, John Fulton (ed.) (Philadelphia and London: W. B. Saunders Company, 1949), pp. 382-398.

[42]Hoyt Sherman, Drawing by Seeing (New York: Hinds, Hayden and Elridge, 1947), pp. 1-77.

concerns itself more with identification, analysis and detail, thus is more critical and tends to lead to reflection and association, not to immediate action.[43]

Gallagher states that in regard to vision in sports and motor skills, it is becoming more apparent that a keen, nearly-perfect, natural vision is not as important a factor in motor learning as was once believed. Gallagher points to the fact that there are a good number of successful athletes in both the collegiate and professional ranks who wear corrective lenses.[44] Winograd also found that visual acuity and various measures of eye-functioning had no significant relationship to the success factor in baseball batting.[45]

Swift studied the acquisition of skill in ball-tossing. He used six subjects in the experiment. Swift discovered that while in the act of tossing the balls, the eyes and attention of the subject appeared to be on the balls in the air. He stated:

> Both the tossing and the catching were executed by the hand alone, for the most part practically outside of the field of vision and of attention . . .[46]

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[43]Sherman, op. cit., pp. 8-17.

[44]James Gallagher, "A Study of Changes in Eye Movement and Visual Focus During the Learning of Juggling," (unpublished Master's thesis, Pennsylvania State University, University Park, Pennsylvania, 1961), p. 21.

[45]Samuel Winograd, "The Relationship of Timing and Vision to Baseball Performance," Research Quarterly, 13:481-494, December, 1942.

[46]Edgar James Swift, "Studies in the Psychology and Physiology of Learning," American Journal of Psychology, 14:201-250, 1903.

In a study of visual perception Vernon stated: "Form perception is so dim and blurred in the periphery that moving objects appear with relatively greater clarity than do stationary ones." She noted that the impression of movement as such, without perception of the moving object, is a characteristic experience in peripheral vision. "Such a movement," stated Vernon, "catches our attention with extreme rapidity and we immediately respond by turning the eyes and the head in order to focus the eyes on it and see it clearly."[47]

Vernon claimed:

> It appears that with practice, the observer is sometimes able to perceive objects without directing his awareness fully upon them. Thus it was found by the author that much practice in the peripheral visual perception of a moving object enables observers to note whether it moved or not without any focusing of awareness on it.[48]

Literature Related to Reaction Time and Speed of Movement Time

Burper and Stroll designed an experiment to test an individual's quick and accurate response to situations in sports. Small and large muscles of four groups of subjects were measured, each group having a different level of success as a participant in physical activities. Burpee and Stroll concluded that there was a significant negative relationship between small muscle reaction time and successful participation in physical education activities. Fast small muscle reaction time was an important factor in attaining success in these activities, and there

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[47] Magdalen D. Vernon, A Further Study of Visual Perception (London: Cambridge University Press, 1952), p. 163.

[48] Vernon, op. cit., pp. 211-212.

was a significant negative correlation between large muscle reaction time and success in physical activities.[49]

Attempting to find the relationship of certain sports skills and reaction time, speed of running, and speed when action requiring dexterity of moving the entire body is necessary, Beise and Peasely found that the skilled group showed a significant difference over the unskilled in reaction time of large muscles, speed of running, and agility. The skilled group also had greater stability in reaction time regardless of the condition under which the stimulus was given.[50]

Westerland and Tuttle conducted a study of 22 varsity track men of short, middle distance, and distance events to determine relationships between running events and reaction time. The reaction time of champions was shorter than any other group regardless of distance, and there was a high degree of relationship between speed in running 75 yards and reaction time.[51]

Total body reaction or response time was not found by Hewes and Peatfield to be a significant factor in baseball hitting ability. These authors further indicated that the means for reaction time when correlated against batting averages were .293 for sound and .319 for light. They went on to indicate that, in their opinion, future studies will show

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[49] Royal H. Burpee and Wellington Stroll, "Measuring Reaction Time of Athletes," Research Quarterly, 7:110-118, March, 1936.

[50] Dorothy Beise and Virginia Peaseley, "The Relation of Reaction Time, Speed, and Agility of Big Muscle Groups to Certain Sport Skills," Research Quarterly, 8:133-142, March, 1937.

[51] J. A. Westerland and W. W. Tuttle, "Relationship Between Running Events in Track and Reaction Time," Research Quarterly, 2:95-100, October, 1931.

that such factors as eyesight, height and weight, coordination, strength and experience are more important to hitting ability than reaction time.[52]

Machworth noted that subjects made a faster response after a preliminary "ready" signal than without it.[53]

In 1950, Slater-Hammel and Stumpner published a study about batting reaction time. Using the speed of a pitched ball traveling from the mound to the home plate as approximately 0.43 - 0.58 seconds, they devised a means of measuring the reaction times of batters. Their results are listed under two headings, as follows:

> Starting Reaction Time . . . . . . Approximately 0.21 second
> (refers to speed with which a batter can start a bat moving upon presentation of a light stimulus.)
>
> Movement Reaction Time . . . . . . Approximately 0.27 second
> (refers to speed with which batter can change the direction of a moving bat upon presentation of a light stimulus.)[54]

Slater-Hammel and Stumpner, using data collected from an earlier study, theorized that the pitched ball could not be closer than 22 to 30 feet from homeplate for a hitter to successfully begin his movement reaction time. This will give the reader some idea of the rapidity with which the batter is required to make up his mind as to whether or not he wants to swing at the ball coming toward the plate.

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[52]Dana T. Hewes, and William R. Peatfield, "The Relationship Between Auditory and Visual Reaction Time and Baseball Hitting Ability," (unpublished Master's thesis, Springfield College, Springfield, Massachusetts, 1956), p. 29.

[53]N. Machworth, Researchers on the Measurements of Human Performances (London: H. M. Stationary Office, 1950), p. 27.

[54]Arthur T. Slater-Hammel and R. L. Stumpner, "Batting Reaction Time," Research Quarterly, 21:353, December, 1950.

The next year, 1951, these two investigators did another study concerned with choice batting reaction times. The authors were of the opinion that a choice reaction time would better simulate the actual batting conditions found in a game, where the batter must make a choice before he decides to swing. The results of this latter study are as follows:

Mean Choice Starting Reaction Time . . . Approximately 0.29 sec.
Mean Choice Movement Reaction Time . . . Approximately 0.34 sec.[55]

In a discussion on reaction time, Morehouse stated that the time required to react to a stimulus is greatly affected by the nature of the stimulus. He added that response to a sound or a touch is quicker than the response to a light signal, but reaction to all types of stimuli will be lengthened if the stimuli are complicated. The data indicated than men react faster than women and that shortest reaction time in both sexes is during the age period between 21 and 30 years, but that there are great differences in reaction time among individuals.[56]

Patrick concluded from his study on the reaction time of basketball players that a reaction time of 1.25 seconds to a visual stimulus is a good indication of potential ability in basketball, and boys with the quickest reaction time are good in other activities. He states also that reaction time can be improved by practice. Reaction was measured by having the subject push a button after the light stimulus was seen by him.[57]

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[55]Slater-Hammel and R. L. Stumpner, "Choice Batting Reaction-Time," Research Quarterly, 22:377, October, 1951.

[56]Lawrence E. Morehouse, Physiology of Exercise (St. Louis: C. V. Mosby Company, 1959).

[57]John Patrick, "Quick Reaction Time Means Athletic Ability," Athletic Journal, 30:68, September, 1949.

Employing athletes and non-athletes to find differences in reaction time, Burley found that all individuals reacted more slowly to complex stimuli than to a simple stimulus. A greater variation in reaction times was scored by all individuals to the complex stimuli than to more simple stimulus.[58]

A study made by Wilkenson measured the reaction time to a visual and a kinesthetic stimulus for 50 non-athletes and 100 athletes, of whom 25 were baseball players, 25 were wrestlers, 25 were football players, and 25 were basketball players. The times from the kinesthetic stimulus indicated that (1) wrestlers had the fastest reaction time, (2) baseball players and football players were not significantly different from each other, and (3) no significant difference existed between basketball players and non-athletes, but both groups were significantly lower than all of the other groups. The results of the visual stimulus indicated that (1) wrestlers and baseball players had significantly quicker reaction time than the other groups, but were not significantly different from each other, (2) football players were significantly faster than basketball players and non-athletes, and (3) basketball players and non-athletes were significantly slower than all other groups, but were not significantly different from each other.[59]

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[58]Lloyd R. Burley, "A Study of the Reaction Time of Physically Trained Men," Research Quarterly, 15-16:232-239, October, 1944.

[59]James J. Wilkenson, "A Study of Reaction Time Measures to a Kinesthetic and a Visual Stimulus for Selected Groups of Athletes and Non-Athletes," (unpublished Doctor's dissertation, University of Indiana, Bloomington, Indiana, 1958), p. 31.

Slater-Hammel and Stumpner reported a study in which they analyzed batting reaction time. Some important findings presented include: A hand-response to a visual stimulus involves a reaction time of anywhere from .150 to .225 of a second; and the time the baseball leaves the pitcher's hand to when it reaches the front of home plate is anywhere from .43 to .58 of a second. This seems to indicate that a batter cannot wait until a pitched baseball is just a few feet in front of home plate to react to the pitch. The writers also conclude that it is better for a batter to make his reaction to a baseball in flight a "starting" reaction, that is, from a set position rather than a moving or change of direction reaction.[60]

Literature Related to Hand-Eye Coordination

The importance of hand-eye coordination was stressed by McCloy when he suggested that it should be an important factor in the testing program.[61] Also, with the other fifteen components of motor educability, it should be tested and explored at each important age level.[62] He also stated that the tests for hand-eye coordination which had been devised had not been validated in the field of physical education.[63]

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[60] Slater-Hammel and Stumper, loc. cit.

[61] C. H. McCloy, Tests and Measurements in Health and Physical Education (New York: Harper and Row, 1963), pp. 466.

[62] C. H. McCloy, "A Preliminary Study of Factors in Motor Educability," Research Quarterly, 11:28-39, May, 1940.

[63] McCloy, op. cit., p. 466.

In 1961 Ross found in physical education literature no standardized tests specifically for measuring hand-eye coordination, so she devised four tests which involve the manipulation of an object. Her four tasks, a ring toss, a ball bounce (below the waist), a wall rebound-catch, (above the waist), and a target throw (using bean bags), all received high reliability scores in a pilot study using the odd-even method with twenty-four subjects, grouped into eight categories each from the second, fourth, and sixth grades.[64]

Wilberg divided hand-eye coordination into two distinct events: (1) the initial visual location of the stimulus, and (2) the motor reaction in response to the situation. In attempting to find the relation of initial visual location of the original stimulus and the motor response when the number of alternatives in the visual field increased, he found that subjects made generally two types of errors: (1) in locating the stimulus object correctly, and (2) incorrect motor response, which was generally due either to loss of perceptual information or incorrect use of the information. The motor response was more often incorrect than the initial visual location of the object.[65]

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[64]Mattie E. Ross, "The Relationship of Eye-Hand Coordination Skills and Visual Perception Skills in Children," (unpublished Doctoral dissertation, Ohio State University, Columbus, Ohio, 1961), pp. 45-46.

[65]Robert B. Wilberg, "Hand-Eye Coordination Determined by the Variability in Visual and Motor Errors," (unpublished Master's thesis, University of Oregon, Eugene, Oregon, 1960), p. 33.

Davis and Lawther noted that highly skilled motor performances seem to involve a great deal of automatic habit performance. In their book, Successful Teaching of Physical Education, they stated:

> The sports and games themselves demand almost constant variation in skill sequences and combination. The performer keeps his attention focused on the perception of cues for the next appropriate behavior while he is responding automatically to cues already received.[66]

His batting pattern adjusts while he focuses intently on the rapidly approaching ball. In basketball he dribbles the basketball and changes rate or direction while he is centering his attention on teammates down the floor ahead of him, estimating their speeds, and their distances from opponents.[67]

Swift studied the acquisition of skill in ball tossing. He used six subjects in the experiment. The research revealed that while in the act of tossing the balls, the eyes and attention of the subjects appeared to be on the balls in the air. He concluded that both the catching and the tossing were executed by the hand alone, for the most part practically outside the field of vision and of attention. Swift further suggested that the method of execution was discovered and improved without conscious effort in the beginning.[68]

According to McDonald, the beginner must learn which clues to respond to, and which to ignore. He noted as a skilled performer learns

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[66]Elwood C. Davis and John D. Lawther, Successful Teaching in Physical Education (New York: Prentice Hall, Inc., 1948), p. 338.

[67]Ibid., p. 338.

[68]Swift, loc. cit.

the cues to respond to, he also learns to respond to fewer cues. A skilled typist, for example can place his fingers in the correct position and move them without looking at his hands or at the letters that he is typing.[69]

The measures of hand-eye coordination that have been devised have been done in the field of psychology. One of the very first to experiment with test instruments was W. R. Miles with his Pursuit Pendulum in 1920[70] and the Pursuitmeter in 1921.[71] The pendulum released water at the height of every arc. The subject attempted to catch the water released in a small cup marked to measure the amount caught. The Pursuitmeter was an electrical instrument with a moving target which changed direction, and thus required great accuracy on the part of the subject. This instrument has since been modified and improved.

The Pursuit Pendulum was the inspiration for the machine designed and built by Wilhelmine Koerth in cooperation with Seashore. Now designated the "Koerth Pursuitmeter," it was built "to measure capacity for the acquisition of skill in coordination of eye and hand." It followed Mile's principle of using a moving stimulus following a fixed path at constant speed.[72] This Koerth Pursuitmeter is the basis for many of the pursuit rotors in use today.

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[69] Frederick J. McDonald, Educational Psychology (San Francisco: Wadsworth Publishing Company, Inc., 1959), p. 312.

[70] Walter R. Miles, "A Pursuit Pendulum," Psychological Review, 27:361-376, September, 1920.

[71] Walter R. Miles, "Pursuitmeter," Journal of Experimental Psychology, 4:77-105, April, 1921.

[72] Wilhelmine Koerth, "A Pursuit Apparatus, Eye-Hand Coordination," Psychological Monographs, 31:288-292, 1922.

Literature Related to Agility

Beise and Peaseley made a study on the relationship of reaction time, speed, and agility of big mucle groups to certain sports skills (tennis, golf, archery), and concluded that the above-named components seem to be fundamental to skill in certain sports activities. They further concluded that training for seven weeks in the sports mentioned above did not significantly affect the original scores on the reaction time, speed, and agility tests.[73]

A review of literature indicates that the two factors most often stated in relation to agility are: (1) control of the body or parts of the body, and (2) efficient and rapid movements or changes of position. Lee and Wagner report that agility may be developed through participation in activities which demand a quick type of motor response, such as squat thrusts, rope jumping, and squat jumps. They also say that vaulting over low obstacles, stunts and tumbling, and games like basketball, are other excellent activities for the development of agility.[74]

In a study by Bennett in which the Burpee Test was used, research indicated that swimming, basketball, and modern dance were superior to folk dance in developing agility, but that there was no significant difference in effectiveness among the three sport activities in this respect.[75]

73Dorothy Beise and Virginia Peaseley, op. cit., pp. 133-142.

74Mable Lee and Miriam W. Wagner, Fundamental of Body Mechanics and Conditioning (Philadelphia: W. B. Saunders Company, 1949), p. 61.

75C. Bennett, "Relative Contribution of Modern Dance, Folk Dance, Basketball, and Swimming to Motor Abilities of College Women," Research Quarterly, 27:253-262, October, 1956.

Ilsley tested agility incorporating pull-ups, vaulting, broad jumping, and a one-hundred yard sprint.[76] Gates and Sheffield administered three batteries of tests which primarily involved the change of direction factor to determine the ability of seventh, eighth, and ninth grade boys. Obstacle runs, shuttle runs, and side stepping drills were incorporated into their test batteries.[77]

The apparent complex nature of agility makes it difficult to measure because most measurements are concerned with one basic type of change of direction. Cumbee, in a factorial analysis of agility tests, discriminates between change of direction factors as she states:

> Two of the variables appearing on this factor, the Burpee and the short potato race, are what physical educators have called "agility" measures. They involve a total body "Quick change of direction." The present writer is hesitant to call this a quick change of direction factor because of the low correlation of the Burpee with this factor . . . . The use of more tests as the side-step, zig-zag and dodging run might give more evidence that the type of ability involved in this factor is a quick change of direction.[78]

Hilsendager, Strow and Ackerman also found that the tests created to test agility do not all test the same factor. They recommend the development of additional agility tests.[79]

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[76]Morrill L. Ilsley, "Study of Correlation in Measurement of Men Students at Pomona College," Research Quarterly, 11:116, March, 1940.

[77]Donald D. Gates and R. P. Sheffield, "Tests of Change of Direction as Measurements of Different Kinds of Motor Ability in Boys of the Seventh, Eighth, and Ninth Grades," Research Quarterly, 11:140-147, October, 1940.

[78]Frances Z. Cumbee, "Factorial Analysis of Motor Coordination," Research Quarterly, 25:418, December, 1954.

[79]Donald R. Hilsendager, Malcolm H. Strow and Kenneth J. Ackerman, "Comparison of Speed, Strength, and Agility Exercises in the Development of Agility," Research Quarterly, 40:75, March, 1969.

Selected agility tests have been found to correlate highly with sports ability. The Brace Test and the Iowa Revision of the Brace Test were reported by McCloy and Young to be highly correlated with sports ability.[80] The Illinois Agility Run was found by Hilsendager, Strow, and Ackerman to be related to sports ability.[81]

Literature Related to the Vertical Jump

The vertical jump is the single test more often used by coaches in determining general athletic ability.[82]

Bovards and Cozens, in studying the relationship between the Sargent Jump and various athletic tests, found that a group of college students exhibiting a high degree of athletic heterogeneity showed a correlation of .55 between the jump and four athletic events. The events were the running high jump, the standing broad jump, the rope-climb for speed, and the 880 yard run. A very small correlation between the Sargent Jump and height and weight was ascertained.[83]

McCloy found experimental evidence for the validity of the Sargent Jump and stated that it was the best single test available for predicting power.[84]

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[80]McCloy and Young, op. cit., pp. 85-90.

[81]Hilsendager, Strow and Ackerman, op. cit., p. 74.

[82]Charles H. McCloyd, Tests and Measurements in Health and Physical Education (New York: Appleton-Century-Crofts, Inc., 1954), p. 142.

[83]J. F. Bovards and F. W. Cozens, "The Leap-Meter," University of Oregon Publication, Eugene, Oregon, Physical Education Series, No. 2, 1928, p. 28.

[84]Franklin Henry, "The Practice and Fatigue Effects in the Sargent Jump," Research Quarterly, 13:16, March, 1942.

Van Dalen stated that track and field events are known as power events and include running, throwing, and jumping, all of which require maximum contraction in the minimum amount of time. He, therefore, assumes that there may be a high relationship between the Sargent Jump and basketball ability because basketball consists chiefly of running, jumping, and throwing.[85]

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[85]Deobald Van Dalen, "New Studies in the Sargent Jump," Research Quarterly, 2:113, May, 1940.

CHAPTER III

METHODS AND PROCEDURES

The following chapter presents the selection of the subjects, methods of obtaining data and measuring the dependent and independent variables.

Source of Data

The subjects were eighteen members of the 1972 South Dakota State University varsity baseball team. They were selected on the basis of making the varsity baseball team, being a right handed batter, and having taken a required number of swings during the indoor practice and regular season competition. Table I indicates the general characteristics of the subjects.

Collection of the Data for the Dependent Variable

The data on dependent variables were collected in three areas: batting against a pitching machine in a batting cage, batting against a pitcher in a batting cage, and batting against opponents' pitching in regular season competition.

Each subject took up to a maximum of twenty-five swings against the pitching machine and twenty-five swings against the live pitching per day during the five week period of indoor practice. The data were collected Monday through Friday for a total of twenty-five days. The criteria for establishing a hit ball was whether or not the ball that was swung at landed in fair territory. In the game situation, fair territory was the area between the foul lines. During indoor batting in the cages, the

TABLE I

CHARACTERISTICS OF THE EIGHTEEN SUBJECTS

Subject	Height feet-inches	Weight pounds	Age years	Batting hand	Position
1. R. B.	5- 7	174	19	right	catcher
2. G. C.	5-11	173	18	right	infielder
3. R. D.	5-10	178	21	right	infielder
4. B. E.	5-11	180	22	right	outfielder
5. G. E.	5-11	175	23	right	outfielder
6. J. F.	6- 3	190	18	right	pitcher
7. R. G.	5-11	160	20	right	pitcher
8. T. O.	5- 6	145	20	right	infielder
9. D. K.	6- 2	218	22	right	infielder
10. K. K.	6- 4	223	19	right	pitcher
11. D. M.	6- 2	180	24	right	outfielder
12. D. Md.	5-11	165	20	right	infielder
13. L. P.	5- 8	165	19	right	outfielder
14. R. P.	5-10	170	18	right	catcher
15. D. P.	5-10	195	21	right	infielder
16. D. S.	5- 9	175	21	right	outfielder
17. B. W.	5-11	180	20	right	catcher
18. R. S.	5-10	165	19	right	catcher

foul lines were drawn on the floor, top and the two sides of the cages to assimilate the fair territory of a regulation field. The foul lines were at a 45 degree angle to the right and left of a straight line from the pitcher's mound to home plate. Where the line on the floor intersected the side wall of the cage, a straight line was drawn up to the top of the cage on both sides. The lines on the top of the cage were in replication of the ones on the floor. Any ball hit within these lines was counted as a hit.

The number of swings indoors ranged from 223 to 512 against the pitching machine and from 52 to 313 against a pitcher. During regular season competition the range was from 52 to 125 swings. Any ball that was swung at and did not land within the defined fair territory was recorded as a miss. The balls that landed within the foul lines were recorded as hits.

The swing-hit ratio was calculated into a percentage by dividing the number of attempts into the number of fair hits. This score was recorded as the subject's swing-hit average.

Collection of data for the indoor practice sessions began on February 22 and ended March 24, 1972. The competitive season data were collected from March 27 to May 8, 1972. During the indoor practice, the subjects batted against the pitching machine and pitchers. The pitching machine was set at a constant speed at the beginning of practice each day. The pitchers from the South Dakota State team were rotated to pitch on different days in order to give each subject a chance to bat against all the pitchers. For regular season competition, the batters batted against whichever pitcher the opponents had throwing. The highest total swings in one game was seventeen. A total of nineteen games were played on twelve different days over a seven week season.

Collection of the Data for the Independent Variable

The variables were selected on the basis of their possible relationship to hitting a baseball. The data collected on these variables were the scores the player obtained in the area of right grip strength, left grip strength, right wrist strength, left wrist strength, trunk strength, leg power, hand-eye coordination, kinesthetic perception, peripheral vision, depth perception, agility, reaction time and speed of movement time.

Measurement of Grip Strength. Grip strength was measured by a cable tensiometer. The instrument measured the amount of tension applied to it by the gripping action of the subject. There are two hands on the dial, one remains at the maximum score that is reached during a given trial while the other hand goes back to the zero mark on the dial. The score is taken from the hand that remains at the maximum tension and is recorded to the nearest whole number. The tension value is converted to pounds by means of a conversion table.

In the present study the subject stood with good balance, knees bent, arm adducted and elbow at a ninety degree angle. The apparatus to which the tensiometer was attached was gripped with the dial face towards the subject. The subject held the wrist of the gripping hand with his opposite hand and gripped the apparatus maximally in one continuous effort.[1] Grip strength was recorded for both the right and left hands. Three trials for each hand were given and the mean of the three was recorded as the subject's score for grip strength.

Measurement of wrist strength. Wrist strength was also measured by a cable tensiometer. Two measurements of wrist strength were taken; one pronation of the right wrist, and the other was supination of the left wrist. The subject was positioned sitting in a desk with his feet flat on the floor and his free arm resting comfortably on his leg. The upper arm was adducted with the elbow flexed to a ninety degree angle and the forearm placed on the desk top. The forearm and wrist were in a position midway between supination and pronation which placed the wrist perpendicular to the table. A strap was fastened around the subject's hand with the D-ring of the strap connected to the cable for the tensiometer. The subject made one constant effort to rotate his right wrist to a pronated position (Figure 1). The strap was changed to the left hand and the subject made one constant effort to rotate his left wrist to a supinated position. His elbow was braced on the side and the wrist was held down and stabilized by the tester.[2] The mean of three trials was recorded for the right wrist (pronation) and left wrist (supination).

Measurement of trunk strength. A cable tensiometer was also used to measure trunk strength. The subject slid the trunk strap up under his

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[1]Paul Hunsicker and George Greey, "Studies in Human Strength," Research Quarterly, 28:118, May, 1957.

[2]H. Harrison Clark, A Manual, Cable-Tension Strength Tests (Springfield College, Springfield, Massachusetts), p. 1-30.

arms as high as possible. He was positioned flat on his back close to the edge of the table with his hips and knees fully extended, feet close together, and arms crossed on his chest with the hand closest to the D-ring on the bottom in direct contact with the strap. The table being used was specially equipped with hooks for attaching the pulling assembly. The pully assembly was attached to the trunk harness which had been tightened firmly to prevent slipping as much as possible. The subject's hips were held down and he was instructed to rotate his trunk to the left in one constant effort (Figure 2). The subjects were told to keep their heads on the table and refrain from any jerking motion.[3] The mean of three trials was recorded.

Measurement of leg power. The Sargent Jump was used to measure the power of the legs. A yardstick, chalk, and a smooth wall surface of at least twelve feet from the floor was needed.[4] With one side toward a wall, the performer stood as tall as possible with his feet flat so that the height of the extended middle finger could be recorded. Chalk dust was then placed on the middle finger. The performer jumped as high as possible touching the board at the top of his jump.[5] The number of inches

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[3]Clark and J. Warren, "Depth Perception and Interpupillary Distance as Factors in Proficiency in Ball Games," American Journal of Psychology, 47:485-487, 1935.

[4]Barry L. Johnson and Jack K. Nelson, Practical Measurement for Evaluation in Physical Education (Minneapolis: Burgess Publishing Company, 1969), p. 81.

[5]Ibid., p. 91.

between the reach and the jump mark was measured to the nearest quarter of an inch. The mean of the three trials was the score recorded.[6]

Measurement of hand-eye coordination. The basketball wall pass test was used to measure hand-eye coordination. The subject stood behind a restraining line drawn nine feet from the wall. On the signal of "begin" he passed the ball against the wall and attempted to catch the rebound and pass it back again as many times as possible for fifteen seconds. For the pass to be good, the subject's feet had to remain behind the restraining line. If the ball went out of control, he had to retrieve it and return to the line and continue passing. The mean of the three trials was the score recorded.[7]

Measurement of depth perception. The apparatus used to measure depth perception consisted of a box twenty-four inches long, eleven and three-quarters inches wide, and twelve and one-half inches high. It was open at the sides and top. The ends of the box nearest the subject being tested had a rectangular window three inches high and seven and one-half inches wide. Inside the instrument were two vertical black rods, one of which was fixed at the center of the box and the other was two inches to the side of the center rod and moved lengthwise on a track. The movable rod was controlled by two strings which were placed in the hands of the subjects at the beginning of the test. A millimeter scale was set along the movable rod track. The center point of the scale, directly opposite

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[6] Johnson and Nelson, op. cit., p. 82.

[7] Ibid., p. 124.

the fixed rod was marked 0, and the scale ranged from 0 to 200 millimeters away from the observer and from 0 to 200 millimeters toward the observer.

The test was explained to each subject and he was allowed to look at the instrument, manipulate the strings, and ask questions about the procedure. He was then seated in a chair twenty feet from the instrument and the test began. At the beginning of each trial the movable rod was placed at the extreme front or back of the instrument. This was done according to a set pattern with the tester standing in front of the instrument so that the rods were hidden from the subject's view. The subject's score for each separate trial was the number of millimeters the movable rod deviated from the fixed rod in the center. Ten trials were recorded, the two highest scores and the two lowest scores were eliminated. The mean of the remaining six scores, rounded to the nearest whole millimeter, was used as the individual's depth perception score.[8]

Measurement of peripheral vision.[9] The apparatus to measure peripheral vision consisted of a flat half-circle with a radius of thirty inches, placed on the horizontal eye level of the subject being tested. Two rods, movable on levers, were fixed, one on each edge of the platform. The two rods were painted a dull black and this was contrasted by the dull

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[8]Einar A. Olsen, "Relationship Between Psychological Capacities and Success in College Athletics," Research Quarterly, March, 1956, 61:79-89.

[9]Marlin Vis, "The Relationship of Forward Pass Catching Ability in Football and Selected Anatomical Measurements and Motor Responses," (unpublished Master's thesis, South Dakota State University, Brookings, South Dakota, 1971), p. 41.

white on the surface of the apparatus. The subject was instructed to immobilize his head with his eyes fixed on a point in front of him on the platform. The operator sat in front of the subject and had control of the levers. The operator moved one of the black rods toward the fixed rod in the center until the subject perceived it in his periphery and gave a command to stop. The subject then indicated which side he saw the rod on. If the response was incorrect it was disregarded and the trial was re-run. Five trials on each side were given for a total of ten correct trials. The order was randomly selected with the two highest and the two lowest scores being disregarded and the mean of the remaining six trials was the subject's score.

Measurement of kinesthetic perception. Kinesthetic perception was measured by the arm raise test. The tester faced the subject whose back was pressed against the Deming Posture Chart. The subject was told to close his eyes and raise his arm sideways to a horizontal position with the palm facing down.[10] After the subject raised his arm to what he felt was a horizontal position, a mark was made on the chart even with the acromion process of the scapula of the shoulder. A second mark was made even with the protruding condyle of the ulna near the little finger. A straight line was drawn between the two marks. A straight line parallel with the floor was then calculated using the mark even with the

[10]Gladys M. Scott, Analysis of Human Motion (New York: F. S. Crofts and Company, 1942), p. 101.

acromion process and the squares on the Deming Posture Chart. The number of degrees to which the subject deviated from the horizontal was measured by a goniometer. Two tests were given for each arm. The score was the mean, to the nearest whole degree, of the four trials.

Measurement of agility. Agility was measured by the side stepping test. Three parallel lines, four feet apart were drawn on the floor. The subject stood astride the middle line, and on the command "go," he sidestepped to the right until his right foot had crossed the line to the right. He then sidestepped to the left until his left foot had crossed the outside line to the left. These movements were repeated as rapidly as possible for ten seconds without crossing the feet. Each trip from the center line to an outside line and back to the center line counted as one.[11] The mean of the three trials was the score recorded.

Measurement of reaction time and speed of movement time. Reaction time and speed of movement time for a swing of the bat was measured by a Hale reaction timer that was electrically connected to starting and stopping devices. The subjects used a 34 inch, 34 ounce bat and took practice swings to determine their stride. They were then instructed to stay in position at the end of their stride. Their back foot was placed on a line two feet behind the device which would stop the clock to indicate the speed of movement time. A command of "ready" was given to the performer to prepare him for the trial. A light was placed 33 feet in

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[11]H. D. Edgren, "An Experiment in the Testing of Ability and Progress in Basketball," Research Quarterly, 3:171-174, 1932.

front of the subject and was controlled by the tester. When the light was switched on, the clocks started. When the subject's bat broke contact with the clip that was attached to the piece of copper tubing fastened to the end of the bat, the reaction clock stopped. The speed of movement clock was stopped by the bat striking a folded section of garden hose covered with screen.

The two separate times were recorded to the nearest hundredth of a second. The two highest and the two lowest scores of ten trials were disregarded. The score for the reaction time and speed of movement time was the mean of the middle six trials.

Procedure for Collecting the Data

Two tests were given to obtain a score on each independent variable for the subjects before conditioning began and after they had practiced baseball for six weeks. The mean of the two tests were recorded as the raw data to be analyzed in this study. For the interest of the reader, the significance of the changes from Test I to Test II can be seen in Appendix D. The first testing began February 1 and ended February 4, 1972, and the second began March 19 and terminated March 21, 1972.

The investigator was assisted in the testing by five graduate assistants from South Dakota State University. Each tester was instructed thoroughly on the mechanics of the test he or she administered. Each tester was given several trials until he or she was familiar with the testing procedures.

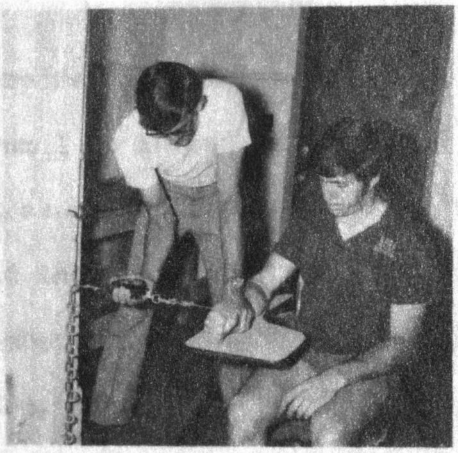

Figure 1.
Right Wrist
(pronation)
Strength Test

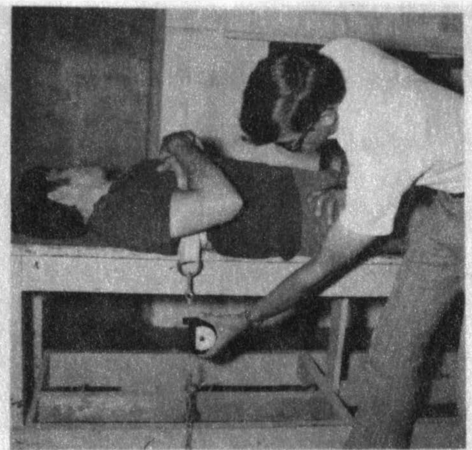

Figure 2
Trunk (rotation)
Strength Test

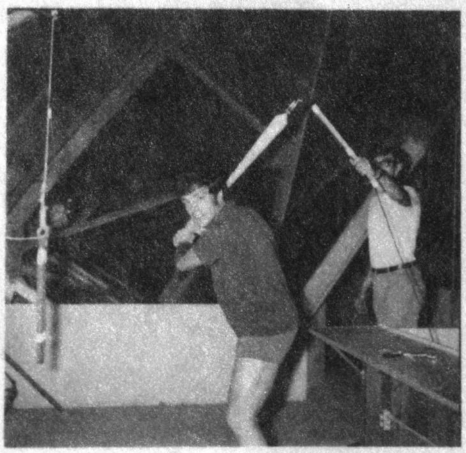

Figure 3
Reaction Time and
Speed of Movement Time
for Batting

The two tests were taken in two different orders, both of which were randomly selected by the subjects. The testing forms were numbered from 1 to 18 and each subject randomly selected a form with a number on it as he entered the testing environment. The front page of each form had the order which that subject was to follow. The subjects with odd numbered forms took the tests in the order of: trunk strength, side step, hand-eye coordination, vertical jump, grip strength, reaction time and speed of movement time, peripheral vision, depth perception, kinesthetic perception, and wrist strength. The subjects with even numbers took the tests in the order of: wrist strength, peripheral vision, depth percpetion, trunk strength, reaction time and speed of movement time, hand-eye coordination, side step, grip strength, vertical jump and kinesthetic perception.

CHAPTER IV

ANALYSIS AND DISCUSSION OF RESULTS

Organization of the Data for Treatment

The investigator identified a total of thirteen independent variables as making possible contributions to successful hitting ability. Data were collected on eighteen subjects for the thirteen independent variables. The independent variables tested were right grip strength, left grip strength, right wrist strength, left wrist strength, trunk strength, kinesthetic perception, peripheral vision, depth perception, reaction time, speed of movement time, hand-eye coordination, agility, and the vertical jump.

Three dependent variables were selected to indicate successful hitting ability. These variables included batting indoors against a pitching machine, batting indoors against live pitchers, and batting against opponents' pitching during a season of competition. In all three cases, the dependent variables were the hit/swing ratio of the subject while batting against the pitching machine, batting against live pitching indoors, and when batting against opponents' pitching during the competitive season.

Due to a decline in the number of subjects, some independent variables had to be eliminated from the statistical analysis in order for the data to meet the prerequisites of the statistical procedure. This decline was due to an insufficient number of swings which certain subjects attempted during indoor batting against live pitching and outdoor batting. The means and standard deviations for the thirteen independent and the dependent variable of hitting success against a pitching machine are presented in Table II. Eleven independent variables and the dependent variable of hitting success against live pitching are presented in Table V. The two variables not included in this analysis were left grip strength and depth perception. They were not included because they were the last two variables selected by the computer to be added to the regression equations for predicting hitting ability against the pitching machine.

Six independent variables and the dependent variable of hitting success against opponents' pitching are listed in Table VIII. The seven variables not included in the analysis were right grip strength, left grip strength, right wrist strength, peripheral vision, depth perception, agility, and vertical jump. They were not included because they were the last seven variables selected by the computer to be added to the regression equation for predicting hitting ability against opponents' pitching during the season. The raw data for the independent variables and the dependent variable for batting against the pitching machine indoors, live pitching indoors, and opponents' pitching appear in Appendix A, B, and C respectively.

In order to be able to predict hitting ability on the basis of the three different sets of independent variables, three multiple correlation matrices and three multiple regression statistical analysis procedures were employed.[1] The procedure first computed intercorrelations

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[1]Robert G. Steel and James H. Torris, Principles and Procedures of Statistics (New York-Toronto-London: McGraw-Hill Book Company, Inc., 1960), pp. 161-182.

between all independent variables and correlations between the independent variables and the dependent variable. Multiple regression equations were then developed beginning with a one variable equation and adding an additional variable in each succeeding step in order to increase the accuracy of the prediction. For each step, a multiple correlation, standard error of estimate, and variance accounted for in that step were computed. An electronic computer was used to facilitate speed and accuracy of the statistical process.

Analysis of Results

This section provides results of the statistical analysis from the data and the developed regression equations.

Indoor batting against the pitching machine. The matrix of zerc order correlations is presented in Table III. There was a low degree of interrelationship among the different independent hitting ability variables, with only fifteen out of the seventy-five intercorrelations being significant beyond the .05 level of confidence. One of the thirteen independent variables showed a significant correlation with the dependent variable. This variable was right grip strength which showed a correlation of .49. This indicated that right grip strength, as measured by the cable tensiometer, is the leading variable of the thirteen investigated in this study for prediction of indoor hitting ability against the pitching machine.

The regression equations computed are shown in Table IV. According to the variance accounted for by the addition of each new variable to the equation, the combination of variables in the third equation accounted for a significant amount of the variance (.017 > .016).

The variance accounted for by the addition of each new variable to the equation after the first three variables was not significant ($.004 < .016$, $.003 < .016$, etc.).

This would indicate that the third equation should be used to predict indoor hitting ability against a pitching machine. However, if a great amount of accuracy is desired, any equation beyond equation number three could be used to further increase the accuracy of the prediction.

Indoor batting against live pitching. The matrix of zero order correlations is presented in Table VI. There was a low degree of interrelationship among the different independent hitting ability variables, with only ten out of fifty-five intercorrelations being significant beyond the .05 level of confidence. None of the eleven independent variables showed a significant correlation with hitting ability although one approached the .05 level of confidence. The one which approached significance was arm raise, showing a correlation of .48. This indicated that kinesthetic perception as measured by the arm raise was the best of the variables used, out of the eleven in the study, for predicting indoor hitting ability against live pitching.

The regression equations computed are shown in Table VII. According to the variance accounted for by the addition of each new variable to the equation, none of the combination of variables developed could significantly predict hitting ability.

TABLE II

MEAN AND STANDARD DEVIATION OF MEASUREMENTS FROM THE EIGHTEEN BASEBALL PLAYERS WHO BATTED AGAINST THE PITCHING MACHINE

	Measurements	Mean	Standard Deviation
X_1	Right Grip Strength (pounds)	114.222	15.203
X_2	Left Grip Strength (pounds)	100.944	13.977
X_3	Right Wrist Strength (pounds)	45.778	6.292
X_4	Left Wrist Strength (pounds)	34.833	5.670
X_5	Trunk Strength (pounds)	107.222	30.115
X_6	Arm Raise (degrees)	4.944	2.287
X_7	Peripheral Vision (degrees)	94.111	2.246
X_8	Depth Perception (centimeters)	10.889	3.984
X_9	Reaction Time (seconds)	.275	.029
X_{10}	Speed of Movement Time (seconds)	.432	.036
X_{11}	Hand-Eye Coordination (passes)	16.556	1.294
X_{12}	Agility (sidesteps)	11.722	.958
X_{13}	Vertical Jump (inches)	23.556	2.572
Y_1	Fair Hit Ratio	.601	.067

TABLE III

CORRELATION MATRIX
BATTING AGAINST PITCHING MACHINE

Variables*	1	2	3	4	5	6	7	8	9	10	11	12	13	Y_1
1	1.00	.75**	.50**	.84**	.59**	-.03	-.09	-.24	.10	-.21	.35	.19	-.15	.49**
2		1.00	.43	.67**	.64**	-.22	.00	-.30	.09	-.19	.25	.13	-.37	.12
3			1.00	.47**	.72**	-.03	-.09	-.72**	.03	-.05	.52**	.54**	.00	.30
4				1.00	.52**	.13	-.14	-.22	.07	-.15	.41	.33	-.34	.24
5					1.00	-.29	.26	-.61**	.07	-.13	.14	.42	.07	.07
6						1.00	-.12	.10	-.06	..11	.21	.15	-.11	.44
7							1.00	-.24	-.29	-.23	-.53**	-.01	-.02	.16
8								1.00	.06	.05	.04	-.24	.03	-.19
9									1.00	.83**	.08	.18	.05	-.12
10										1.00	-.05	-.14	-.05	-.17
11											1.00	.32	.13	.25
12												1.00	.02	-.03
13													1.00	.13
Y_1														1.00

* 1 Right Grip Strength
2 Left Grip Strength
3 Right Wrist Strength
4 Left Wrist Strength
5 Trunk Strength
6 Arm Raise
7 Peripheral Vision
8 Depth Perception
9 Reaction Time
10 Speed of Movement Time
11 Hand-Eye Coordination
12 Agility
13 Vertical Jump
Y_1 Fair Hit Ratio

** (.05 level of confidence = .47)

TABLE IV

REGRESSION EQUATIONS DEVELOPED, THEIR STANDARD ERROR OF ESTIMATE, MULTIPLE CORRELATION AND VARIANCE ACCOUNTED FOR BY THE ADDITION OF EACH VARIABLE.

Regression Equation	Standard Error of Estimate	Multiple Correlation	Variance Accounted*
1. $Y_1 = .002X_1 + .354$	.060	.489	.018
2. $Y_1 = .002X_1 + .014X_6 + .280$	.053	.672	.016
3. $Y_1 = .006X_1 + .018X_6 - .011X_4 + .247$	.042	.820	.017
4. $Y_1 = .006X_1 + .018X_6 - .010X_4 + .007X_7 - .406$	.040	.850	.004
5. $Y_1 = .005X_1 + .017X_6 - .011X_4 + .010X_7 + .013X_{11} - .921$	.039	.873	.003
6. $Y_1 = .006X_1 + .015X_6 - .010X_4 + .014X_7 + .016X_{11} - .001X_5 - .1.276$	.037	.894	.003
7. $Y_1 = .006X_1 + .013X_6 - .009X_4 + .014X_7 + .007X_{11} - .001X_5 + .005X_3 - 1.384$	.033	.926	.004
8. $Y_1 = .005X_1 + .012X_6 - .006X_4 + .015X_7 + .00X_{11} - .002X_5 + .006X_3 + .006X_{13} - 1.553$	.030	.945	.003
9. $Y_1 = .005X_1 + .013X_6 - .005X_4 + .016X_7 + .001X_{11} - .002X_5 + .007X_3 + .007X_{13} - .014X_{12} - 1.462$	.028	.957	.002
10. $Y_1 = .005X_1 + .013X_6 - .005X_4 + .016X_7 - .001X_{11} - .002X_5 + .007X_3 + .007X_{13} - .015X_{12} + .082X_9 - 1.529$	.030	.958	.000

TABLE IV (Continued)

Regression Equation	Standard Error of Estimate	Multiple Correlation	Variance Accounted*
11. $Y_1 = .004X_1 + .014X_6 - .004X_4 + .016X_7 - .001X_{11} - .002X_5 + .008X_3 + .006X_{13} - .022X_{12} + .775X_9 - .585X_{10} - 1.357$	.030	.963	.001
12. $Y_1 = .003X_1 + .017X_6 - .003X_4 + .017X_7 - .010X_{11} - .002X_5 + .013X_3 + .007X_{13} - .031X_{12} + 1.174X_9 - .900X_{10} + .004X_8$ 1.366	.031	.968	.001
13. $Y_1 = .003X_1 + .017X_6 - .002X_4 + .018X_7 - .014X_{11} - .002X_5 + .014X_3 + .009X_{13} - .032X_{12} + 1.149X_9 - .872X_{10} + .005X_8$ $.001X_2 - 1.465$	.034	.969	.000

* Total Variance .077
MS Variance .00167
F_{05} (1/3) = 10.13; LSD = .00167 x 10.13 = .0169

TABLE V

MEAN AND STANDARD DEVIATION OF MEASUREMENTS FROM THE SIXTEEN BASEBALL PLAYERS WHO BATTED AGAINST A PITCHER INDOORS

	Measurements	Mean	Standard Deviation
X_1	Right Grip Strength (pounds)	114.688	16.094
X_3	Right Wrist Strength (pounds)	46.438	5.573
X_4	Left Wrist Strength (pounds)	34.563	5.796
X_5	Trunk Strength (pounds)	109.750	28.340
X_6	Arm Raise (degrees)	4.938	2.175
X_7	Peripheral Vision (degrees)	94.375	2.217
X_9	Reaction Time (seconds)	.274	.031
X_{10}	Speed of Movement Time (seconds)	.433	.038
X_{11}	Hand-Eye Coordination (passes)	16.563	1.365
X_{12}	Agility (sidesteps)	11.750	1.000
X_{13}	Vertical Jump (inches)	23.438	2.394
Y_2	Fair Hit Ratio	.584	.119

TABLE VI

CORRELATION MATRIX
BATTING AGAINST PITCHING INDOORS

Variable*	1	3	4	5	6	7	9	10	11	12	13	Y_2
1	1.00	.61**	.88**	.67**	-.06	-.12	.11	-.22	.36	.20	-.13	.15
3		1.00	.78**	.63**	.24	-.34	.06	-.06	.55**	.52**	-.24	.17
4			1.00	.77**	.02	-.06	.07	-.16	.46	.41	-.29	.14
5				1.00	-.14	.14	.09	-.15	.10	.38	-.11	-.17
6					1.00	-.06	-.06	.11	.30	.27	.12	.48
7						1.00	-.29	-.27	-.60**	-.08	-.06	-.09
9							1.00	.84**	.08	.19	.04	-.29
10								1.00	-.04	-.03	-.02	-.37
11									1.00	.31	.08	.43
12										1.00	-.06	.21
13											1.00	.01
Y_2												1.00

* 1 Right Grip Strength
3 Right Wrist Strength
4 Left Wrist Strength
5 Trunk Strength
6 Arm Raise
7 Peripheral Vision
9 Reaction Time
10 Speed of Movement Time
11 Hand-Eye Coordination
12 Agility
13 Vertical Jump
Y_2 Fair Hit Ratio

** (.05 level of confidence = .50)

TABLE VII

REGRESSION EQUATIONS DEVELOPED, THEIR STANDARD ERROR OF ESTIMATE, MULTIPLE CORRELATION, AND VARIANCE ACCOUNTED FOR BY THE ADDITION OF EACH VARIABLE

Regression Equation	Standard Error of Estimate	Multiple Correlation	Variance Accounted*
1. $Y_2 = .026X_6 + .455$	.108	.477	.048
2. $Y_2 = .024X_6 - 1.335X_{10} + 1.020$	.098	.641	.039
3. $Y_2 = .024X_6 - 1.271X_{10} + .024X_{11} + .616$	.096	.692	.015
4. $Y_2 = .022X_6 - 1.353X_{10} + .027X_{11} - .001X_5 + .716$	.096	.723	.009
5. $Y_2 = .026X_6 - 2.578X_{10} + .021X_{11} - .001X_5 + 1.704X_9 + .892$	.096	.751	.009
6. $Y_2 = .026X_6 - 2.549X_{10} + .009X_{11} - .002X_5 + 1.717X_9 + .007X_4 + .942$	.098	.771	.006
7. $Y_2 = .027X_6 - 2.649X_{10} + .012X_{11} - .002X_5 + 1.833X_9 + .006X_4 - .004X_{13} + 1.027$	.103	.773	.001
8. $Y_2 = .027X_6 - 2.788X_{10} + .010X_{11} - .002X_5 + 2.003X_9 + .008X_4 - .003X_{13} - .001X_1 + 1.067$	.110	.774	.000
9. $Y_2 = .028X_6 - 3.044X_{10} + .009X_{11} - .002X_5 + 2.335X_9 + .009X_4 - .003X_{13} - .001X_1 - .007X_{12} + 1.187$	.119	.775	.000
10. $Y_2 = .029X_6 - 3.134X_{10} + .007X_{11} - .002X_5 + 2.426X_9 + .010X_4 - .003X_{13} - .002X_1 - .009X_{12} - .001X_7 + 1.352$	.130	.775	.000

TABLE VII (Continued)

Regression Equation	Standard Error of Estimate	Multiple Correlation	Variance Accounted*
11. $Y_2 = .029\ X_6 - 3.135X_{10} + .007X_{11} - .002X_5 + 2.428X_9 + 010X_4$ $.003X_{13} - .002X_1 - .009X_{12} - .001X_7 + .000X_3 + 1.349$	.146	.775	.000

* Total Variance .213
MS Variance .0283
F_{05} (1/3) = 10.13; LSD = .0283 x 10.13 = .2867

Batting against opponents' pitching. The matrix of zero order correlation is presented in Table IX. There was a very low degree of relationship among the different independent hitting ability variables, with only one out of fifteen intercorrelations being significant beyond the .05 level of confidence. None of the six independent variables showed a significant correlation with hitting ability at the .05 level of confidence.

The regression equations computed are shown in Table X. According to the variance accounted for by addition of each new variable to the equation, none of the combination of variables developed could significantly predict hitting ability. It must be pointed out, however, that the multiple correlation showed a relatively high relationship between the independent variables and hitting ability against opponents' pitching in games. This can be seen by Equations 4, 5, and 6 which resulted in multiple correlations of .928, .969 and .976 respectively. This would indicate that from a practical point of view, hitting ability against opponents' pitching in games can be predicted with reasonable accuracy.

Discussion of Results

The two hypotheses stated that: 1. There is no significant relationship between hitting a baseball and selected anatomical measurements and motor responses, and, 2. A multiple regression equation to significantly predict hitting ability in baseball cannot be developed. When applied to indoors batting against live pitching, both hypotheses were accepted since none of the correlations were significant nor were any of the developed regression equations significant. Also, both hypotheses

TABLE VIII

MEAN AND STANDARD DEVIATION OF MEASUREMENTS FROM THE TEN BASEBALL PLAYERS WHO BATTED AGAINST OPPONENT'S PITCHING DURING GAMES

	Measurements	Mean	Standard Deviation
X_4	Left Wrist Strength (pounds)	34.400	7.168
X_5	Trunk Strength (pounds)	109.300	34.026
X_6	Arm Raise (degrees)	5.700	2.003
X_9	Reaction Time (seconds)	.275	.037
X_{10}	Speed of Movement Time (seconds)	.429	.042
X_{11}	Hand-Eye Coordination (passes)	16.800	1.476
Y_3	Fair Hit Ratio	.449	.054

TABLE IX

CORRELATION MATRIX
BATTING AGAINST OPPONENT'S PITCHING DURING GAME

Variable *	4	5	6	9	10	11	Y_3
4	1.00	.79	.17	-.00	-.24	.61	.29
5		1.00	-.01	.03	-.20	.30	-.24
6			1.00	-.11	.06	.28	.42
9				1.00	.89**	.20	-.41
10					1.00	.03	-.42
11						1.00	.15
Y_3							1.00

* 4 Left Wrist Strength
5 Trunk Strength
6 Arm Raise
9 Reaction Time
10 Speed of Movement Time
11 Hand-Eye Coordination
Y_3 Fair Hit Ratio

** (.05 level of confidence = .81)

TABLE X

REGRESSION EQUATION DEVELOPED, THEIR STANDARD ERROR OF ESTIMATE, MULTIPLE CORRELATION, AND VARIANCE ACCOUNTED FOR BY THE ADDITION OF EACH VARIABLE

Regression Equation	Standard Error of Estimate	Multiple Correlation	Variance Accounted*
1. $Y_3 = .011X_6 + .384$	.052	.421	.005
2. $Y_3 = .012X_6 - .006X_{10} + .624$	.049	.611	.005
3. $Y_3 = .012X_6 - .007X_{10} - .001X_5 + .718$	.048	.694	.003
4. $Y_3 = .007X_6 - .005X_{10} - .002X_5 + .008X_4 + .553$	.027	.928	.010
5. $Y_3 = .008X_6 - .004X_{10} - .002X_5 + .011X_4 - .014X_{11} + .682$	.020	.969	.002
6. $Y_3 = .010X_6 - .009X_{10} - .002X_5 + .011X_4 - .016X_{11} + .005X_9$ .760	.020	.976	.000

* Total Variance .027
MS Variance .001
$F_{.05}$ (1/2) = 18.51; LSD = .001 x 18.51 = .0185

were accepted when applied to batting against opponents' pitching during a game situation since none of the correlations were significant and neither were any of the regression equations significant. However, the two hypotheses applying to batting against the pitching machine indoors were rejected since the computed F ratio for the variance accounted for by the third equation was above that necessary for significance at the .05 level of confidence (.017 > .016) and there was a significant correlation between right grip strength and hitting ability against a pitching machine.

In reviewing the literature, the investigator found few studies that correlated hitting success with the same or similar measures used in this study. The areas that have been tested in other studies are depth perception, hand-eye coordination, left grip strength, and right grip strength.

In the present study depth perception was found to have a low correlation with hitting against a batting machine (.19). This is in agreement with Olsen who stated that little, if any, relationship exists between the ability to discriminate the distance of objects and motor performance (.075).[2] In his investigation of the relation of vision to baseball performance, Winograd tested the eye on eleven various measures, one of which was depth perception. He found that visual acuity and

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[2]Einar A. Olsen, "Relationship Between Psychological Capacities and Success in College Athletics," Research Quarterly, 27:79-89, March, 1956.

various measures of eye-functioning had no significant relationship to the success factor in baseball batting.[3] Montebello, in a study on depth perception, also found a low correlation between depth perception and batting averages over a one year season (.25).[4]

Hand-eye coordination showed a low correlation for all the areas of testing: .25 when batting against the pitching machine indoors, .43 when batting against live pitching indoors, and .15 when batting against opponents' pitching. These findings differ from those of Bates who noted that there was an .81 correlation between batting averages and hand-eye coordination among high school baseball players. In addition he concluded that hand-eye coordination could be used to predict batting ability.[5]

In this study, left grip strength correlated very low with hitting ability against the pitching machine (.12). This is consistent with Hooks who also found a low correlation (.36) for left grip strength.[6] However, for right grip strength there were conflicting results. Hooks

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[3]Samuel Winograd, "The Relationship of Timing and Vision to Baseball Performance," Research Quarterly, 13:481-494, December, 1942.

[4]Robert Albert Montebello, "The Role of Stereoscopic Vision in Some Aspects of Baseball Playing Ability," (unpublished Master's thesis, Ohio State University, Columbus, Ohio, 1953), pp. 60-62.

[5]Frank H. Bates, "Relationship of Hand and Eye Coordination to Accuracy in Baseball Batting," (unpublished Master's thesis, State University of Iowa, Iowa City, 1948), p. 7.

[6]Gene Hooks, "Prediction of Baseball Ability Through an Analysis of Measures of Strength and Structure," Research Quarterly, 30:38-43, March, 1959.

reported a correlation of .32[7] for right grip strength whereas in this study right grip strength correlated significantly with hitting success when batting against the pitching machine indoors (.49) and can be used as a predictor of success in this area. Right grip strength, however, dropped to a low correlation of (.12) for batting against live pitching indoors. Apparently the relationship between right grip strength and hitting ability is somewhat dependent on the means whereby hitting ability is measured.

A possible explanation for the variable of right grip strength not correlating highly throughout the study is that the batter may swing differently in different hitting environments and hitting situations. The one change most evident between the pitching machine and the other two hitting areas was that the machine threw all pitches the same and at the same speed. However, when batting against a pitcher, the type of pitch and speed of the pitch was consistently being changed. This took the anticipation advantage away from the batter when batting against a pitcher.

The investigator had anticipated more of a correlation between wrist strength and hitting success because of a statement made by Cooper and Glassow who emphasized the importance of strong wrists. They believed that a bat had to be moved rapidly if the potential wrist action was to be realized.[8] Ted Williams also stated that one must have strong, quick

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[7]Ibid.

[8]John M. Cooper and Ruth B. Glassow, Kinesiology (St. Louis: The C. V. Mosby Company, 1963), pp. 85-88.

hands and wrists to be a good hitter.[9] However, in the current study, none of the correlations between hitting ability and wrist strength surpassed .30. This could indicate that quick wrists are more important than strong wrists and that the two variables may not have a high intercorrelation.

In the present study, the relationship between reaction time and hitting ability did not surpass .42 for the three areas tested. None of these were found to be significant. This is in agreement with Hewes and Peatfield who found that total body reaction or response time was not a significant factor in baseball hitting ability. They found a correlation of .319 between reaction time and ability to hit a baseball.[10]

In summary, the investigator would like to note that he had expected more significant correlations between the independent variables and hitting success. It was felt that the selected criterion used, hitting the ball in fair territory, was the best for judging hitting ability. This criterion does have a weakness, however, in that no attempt was made to judge how well a fair ball was hit. It may have been interesting in the outdoor criterion of batting against opponents' pitching, to have used the season's batting average as the criterion. The investigator, however, supports the chosen criterion because it seems logical that the greater number of balls hit fair would give the batter a

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[9]Ted Williams, "How To Be a Better Hitter," Scholastic Coach, 25:8, April, 1956.

[10]Dana T. Hewes, and William R. Peatfield, "The Relationship Between Auditory and Visual Reaction Time and Baseball Hitting Ability," (unpublished Master's thesis, Springfield College, Springfield, Massachusetts, 1956), p. 39.

better opportunity to get a hit or reach base safely. He also feels that if all eighteen subjects would have been able to take a sufficient number of swings, some significant findings may have appeared in batting against opponents' pitching. This is particularly apparent when one analyzes the developed regression equations. None of the equations were statistically significant. Yet, if one looks at the multiple correlations, it is apparent that hitting ability can be predicted with reasonable accuracy. Therefore from a practical point of view, anyone interested in predicting hitting ability can do so by using the four variables of arm raise, speed of movement time, trunk strength, and left wrist strength.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to investigate the relationship between the independent variables of right grip strength, left grip strength, right wrist strength, left wrist strength, trunk strength, kinesthetic perception, peripheral vision, depth perception, reaction time, speed of movement time, hand-eye coordination, agility, and leg power with the ability of a batter to hit a baseball. A secondary purpose was to develop a regression equation from the independent variables which could be used to predict hitting success.

Eighteen South Dakota State University varsity baseball players of the 1972 baseball season were tested on the thirteen independent anatomical measurements and motor responses. From intercorrelations and correlations between the independent variables and dependent success criterion of individual hits against the pitching machine indoors, live pitching indoors, and opponents' pitching during game situations, three separate correlation matrices and regression equation tables were developed for the purpose of predicting hitting ability.

The results of the study showed that right grip strength correlated significantly with hitting success when batting against the pitching machine. Also, hitting success against the pitching machine could be significantly predicted by using the three independent variables of right grip strength, arm raise, and left wrist strength ($R=.820$).

The second result found was that none of the independent variables correlated significantly with hitting success when batting against live pitching indoors, and that no statistically significant regression equation was developed to predict hitting ability when batting against live pitching indoors. The highest value the multiple correlation reached was .775 and this occurred when all eleven independent variables were combined to predict hitting success. Therefore, from a practical point of view, hitting success against live pitching indoors could not be predicted with any degree of accuracy.

The third result found was that none of the independent variables correlated significantly with hitting success when batting against opponents' pitching during the season. Also, no statistically significant regression equation was developed to predict hitting ability when batting against opponents' pitching during the season. However, because of the magnitude of the multiple correlations ($R=.928$), it is apparent that hitting ability can be predicted with reasonable accuracy. Anyone interested in predicting hitting ability can do so by using the four variables of arm raise, speed of movement time, trunk strength, and left wrist strength.

Conclusion

Due to the results of this study and within the limitations, the investigator concludes:

1. Only one independent variable related significantly to hitting ability against the pitching machine indoors. This variable was right grip strength.

2. Hitting ability against the pitching machine indoors can be significantly predicted from a combination of at least three independent variables. These variables are right grip strength, arm raise, and left wrist strength.

3. Hitting ability against live pitching indoors cannot be predicted with statistical significance from the combination of variables used in this study. Furthermore, there is no significant relationship between the independent variables and hitting ability against live pitching indoors.

4. Hitting ability against opponents' pitching during game situations cannot be predicted with statistical significance from the combination of variables used in this study. Furthermore, there is no significant relationship between the independent variables and hitting ability against opponents' pitching during the season.

5. Although none of the equations for batting against opponents' pitching during game situations were statistically significant, the magnitude of the multiple correlations ($R=.928$), makes it apparent that hitting ability can be predicted with reasonable accuracy. From a practical point of view, anyone interested in predicting hitting ability can do so by using the four variables of arm raise, speed of movement time, trunk strength, and left wrist strength.

Recommendations

Based on the findings of this study, the investigator proposed the following recommendations for further study.

1. That further study be conducted employing the same procedures and statistical design, but that a large number of subjects be used.

2. That a study be conducted on the relationship of strength to the various gripping positions of the hands on the bat and the ability to hit a baseball.

3. That further study be conducted employing the same procedures and statistical design, but that a different criterion be used to judge hitting success.

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APPENDICES

APPENDIX A

TABLE XI

THE RAW DATA, MEANS AND STANDARD DEVIATIONS OF THE THIRTEEN INDEPENDENT VARIABLES AND THE ONE DEPENDENT VARIABLE FOR THE EIGHTEEN SUBJECTS USED IN THE STUDY

Subjects	Right Grip Strength	Left Grip Strength	Right Wrist Strength	Left Wrist Strength	Trunk Strength	Arm Raise	Peripheral Vision	Depth Perception	Reaction Time	Speed of Movement Time	Hand-Eye Coordination	Agility	Vertical Jump	Hit/Swing Ratio
1	113	99	32	41	52	8	91	18	.28	.43	16	11	21	.546
2	107	109	45	30	109	5	96	5	.25	.41	16	10	24	.630
3	135	123	49	40	134	3	97	9	.24	.39	16	11	23	.676
4	114	91	51	35	116	9	95	8	.25	.41	17	13	25	.634
5	119	107	49	33	139	5	94	9	.33	.48	15	13	24	.602
6	127	101	43	37	130	3	94	10	.30	.48	15	10	24	.578
7	108	85	49	33	122	2	93	10	.28	.42	17	12	28	.536
8	140	123	58	48	176	7	94	8	.26	.40	19	13	24	.670
9	121	123	50	38	128	1	93	10	.27	.40	17	12	18	.503
10	117	107	47	35	101	4	92	13	.35	.50	19	12	27	.611
11	113	92	43	31	96	3	94	10	.24	.36	16	12	28	.638
12	76	72	36	23	69	6	96	18	.25	.44	16	11	25	.549
13	97	82	44	29	72	6	96	9	.28	.46	15	11	22	.669
14	111	98	42	34	100	2	96	15	.26	.42	16	12	23	.533
15	137	99	49	41	89	8	94	12	.28	.43	18	12	21	.758
16	105	106	44	36	127	5	98	7	.29	.45	15	13	21	.522
17	103	95	54	34	89	6	89	7	.27	.47	18	12	22	.552
18	113	105	39	29	81	6	92	18	.27	.42	17	11	24	.616
$\bar{X}$	114	101	46	35	107	5	94	11	.28	.43	17	12	24	.601
SD	15	14	6	6	30	2	2	4	.03	.04	1	1	3	.07

APPENDIX B

TABLE XII

THE RAW DATA, MEANS AND STANDARD DEVIATIONS OF THE ELEVEN INDEPENDENT VARIABLES AND THE ONE DEPENDENT VARIABLE FOR THE SIXTEEN SUBJECTS USED IN THE STUDY

Subjects	Right Grip Strength	Right Wrist Strength	Left Wrist Strength	Trunk Strength	Arm Raise	Peripheral Vision	Reaction Time	Speed of Movement Time	Hand-Eye Coordination	Agility	Vertical Jump	Hit/Swing Ratio
2	107	45	30	109	5	96	.25	.41	16	10	24	.469
3	135	49	40	134	3	97	.24	.39	16	11	23	.701
4	114	51	35	116	9	95	.25	.41	17	13	25	.570
5	119	49	33	139	5	94	.33	.48	15	13	24	.507
6	127	43	37	130	3	94	.30	.48	15	10	24	.344
8	140	58	48	176	7	94	.26	.40	19	13	24	.694
9	121	50	38	128	1	93	.27	.40	17	12	18	.542
10	117	47	35	101	4	92	.35	.50	19	12	27	.558
11	113	43	31	96	3	94	.24	.36	16	12	28	.672
12	76	36	23	69	6	96	.25	.44	16	11	25	.655
13	97	44	29	72	6	96	.28	.46	15	11	22	.615
14	111	42	34	100	2	96	.26	.42	16	12	23	.385
15	137	49	41	89	8	94	.28	.43	18	12	21	.788
16	105	44	36	127	5	98	.29	.45	15	13	21	.558
17	103	54	34	89	6	89	.27	.47	18	12	22	.590
18	113	39	29	81	6	92	.27	.42	17	11	24	.693
X	115	46	35	110	5	94	.27	.43	17	12	23	.584
SD	16	6	6	28	2	2	.03	.04	1	1	2	.119

APPENDIX C

TABLE XIII

THE RAW DATA, MEANS AND STANDARD DEVIATIONS OF THE SIX INDEPENDENT VARIABLES AND THE ONE DEPENDENT VARIABLE FOR THE TEN SUBJECTS USED IN THE STUDY

Subjects	Left Wrist Strength	Trunk Strength	Arm Raise	Reaction Time	Speed of Movement Time	Hand-Eye Coordination	Hit/Swing Ratio
3	40	134	3	.24	.39	16	.441
4	35	116	9	.25	.41	17	.476
5	33	139	5	.33	.48	15	.364
8	48	176	7	.26	.40	19	.448
10	35	101	4	.35	.50	19	.400
11	31	96	3	.24	.36	16	.476
12	23	69	6	.25	.44	16	.398
13	29	72	6	.28	.46	15	.496
15	41	89	8	.28	.43	18	.553
18	29	81	6	.27	.42	17	.438
X	34	109	6	.28	.43	17	.449
SD	7	34	2	.04	.04	1	.054

APPENDIX D

TABLE XIV

RESULTS OF THE CHANGES OF THE INDEPENDENT VARIABLES FROM TEST I TO TEST II

Variable	Test I Mean	Test II Mean	$\bar{d}$	$SE_{\bar{d}}$	t*
Right Grip Strength (pounds)	114.61	113.22	- 1.39	3.50	.40
Left Grip Strength (pounds)	100.17	101.28	+ 1.11	1.90	.58
Right Wrist Strength (pounds)	44.33	46.72	+ 2.39	1.57	1.52
Left Wrist Strength (pounds)	33.22	35.89	+ 2.67	1.54	1.73
Trunk Strength (pounds)	100.89	113.06	+12.17	5.51	2.21
Arm Raise (degrees)	4.94	4.50	- .44	.69	.64
Peripheral Vision (degrees)	93.61	94.00	+ .39	.52	.75
Depth Perception (millimeters)	11.67	9.78	- 1.89	1.44	1.31
Reaction Time (seconds)	.280	.265	- .015	.007	2.14

TABLE XIV (Continued)

Variable	Test I Mean	Test II Mean	$\bar{d}$	$SE_{\bar{d}}$	$\underline{t}$*
Speed of Movement Time (seconds)	.430	.429	-.0011	.0062	.18
Hand-Eye Coordination (passes)	15.83	16.77	+.94	.17	5.53
Agility (sidesteps)	10.94	11.89	+.95	.33	2.88
Vertical Jump (inches)	23.50	23.17	-.33	.40	.82

*$\underline{t}_{.05}(17) = 2.11$, $\underline{t}_{.01}(17) = 2.90$